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Supervised Project Report
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What on Earth could live on Mars?

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Abstract/executive summary (ca. 200 words):

This project explores the similarities and differences of climate between the Antarctic Dry Valleys and Mars. Specifically looking into possible locations where the cyanobacteria *Chroococcidiopsis* could survive. It goes on to explain the limitations of the knowledge around this cyanobacteria and the Martian climate. Following this the question is posed, if we can colonise Mars, should we? It then explores the reasons why we should/should not colonise space both as humans and with organisms we place there. This is presented via a video in combination with a referenced script and explanation.

What on Earth could live on Mars?

A discussion on the possibilities and issues surrounding the colonization of other worlds.

Introduction and Why

The interaction between Mars and Antarctica has always interested me. I have always been fascinated by space and the completely alien worlds that we share a solar system with. I had always heard some vague links between Mars and Antarctica, but it wasn't until Paul Broady's lecture in Anta 103 that I first saw a striking comparison. Two pictures were shown to me, one of the dry valleys and one of the Martian surface. I found it very difficult to distinguish between the two images. The one of the dry valleys could easily have been from another planet.

This is what first sparked this thought in my head. What If there is something so adapted to life in the extremes that it could potentially survive in the cold alien landscape of Mars? Throughout my degree I gradually found out more about Mars and Antarctica, but nothing that really directly compared the climates and potential habitats of the two. You can see now that this project was not just something I picked out of the blue, but something I have wanted to know for a long time.

How to go about it though? I could have written a scientific report, like I have several times throughout my degree. But writing has never been something I overly enjoyed, and after reading so many scientific papers, experiencing the difficulty of accessing them and understanding them. I have concluded that they are only of true use to scientists. If science is to be better understood by the populace. If policies and decisions are to be made with scientific understanding, then communicating science must be done in a way that anyone can comprehend.

I therefore modelled my final project on a YouTube channel called Minute Physics. The man running this channel uses simple hand drawn images to explain complicated physics in a manner that even someone with no physics background could understand. The method of delivery through YouTube ensures that it is accessible to a wide audience, unlike the restrictions placed on scientific papers. The style in which the video is presented ensures that it is easy to understand and interesting to follow for most of the population.

My biggest challenge then was to create this video in a similar manner. I have zero experience in recording or making videos and this project has taken far, far longer then I assumed it would. It is not a masterpiece and indeed I believe my lack of experience shows through. However on the whole I am happy at least with the overall message I am conveying, and the way in which it is being presented.

I hope that you take this into account when viewing it: That it is not meant for someone of vast scientific knowledge, that it is my first video, and even that I actually have no experience in Biology. This project has been a jump in the deep end without knowing if I could swim right from the start. I have found I am no Olympic swimmer, but at least I can float. I did not take this course for an easy ride through things I have already studied. I took it to look in greater detail at things I knew nothing about. In that, I believe I have succeeded. That it was worth the sleepless nights and the things that went wrong along the way.

Therefore, I thank you for taking the time to look and listen to what I have found and learned.

Referenced Script

Life, it and the blue oceans so obvious from space are what distinguish our planet from the other worlds in our solar system. A relatively warm haven in which things can grow and prosper, even earth has its harsh extremities.

Antarctica, often known as the last continent, is located at the bottom of the world. A land almost entirely covered in ice and snow it is the highest, driest and coldest continent on the planet. Contained within it are some of the harshest environments we know of in which life exists.

The McMurdo dry valleys in the Transantarctic Mountains are one such location. Classified as a Hyper-Arid Polar Desert, they have very low snowfall and zero rainfall, most of the snow that does make it being blown off the polar plateau. Spending winter in darkness with summer temperatures of much less than 10°C these valleys compare to nothing else on our planet.[9]

Yet life still exists here. Not the life we are used to, the large creatures, people and plants that inhabit the rest of the world. But microbial life hanging on in a location where nothing else survives.

The dry valleys are often called the closest thing we have to Mars on Earth. This is not just due to their incredibly similar looks, but also the conditions. Mars is classed as a global Hyper-Arid Polar Desert, retaining the same classification as Antarctica but on a global scale.[9]

The question is then: If life survives in the dry valleys, could it survive Mars? To help answer this let us compare these climates a bit more closely.

The Dry Valleys, located in southern Victoria Land, are a series of valleys extending up to 80km long and 15km wide. With very low levels of precipitation and melt water, they are a mostly ice free zone. Conditions here are so arid, ice often sublimes straight to vapour (transforms from ice to vapour without passing through the liquid water state). When melt water does occur, it can infiltrate the soil by a few centimetres. Upon evaporation, salts are left behind. This allows salty briny water to occur, forming small hyper saline lakes, many times saltier then the ocean. This brine has a much lower freezing point then pure water and in some circumstances has been recorded as a liquid down to -40°C.[9]

Temperatures in the dry valleys can fluctuate from 10°C in summer to -65°C in winter, with a summer mean of -10°C. Microclimates occur inside the rock, making it possible for temperatures between the air and rock to differ by up to 18°C. This means it can be warmer inside the rock then on the surface.[9]

Mars on the other hand, particularly closer to the equator has a temperature range of -113°C up to the 35°C maximum recorded by the Spirit rover.[5] Mars also has seasons and a varying night and day temperature cycle. Albeit one that can get a little bit colder! Precipitation is also incredibly low on Mars and liquid water is so far, non-existent. This is due to the incredibly low atmospheric pressure, around 1/100th that of the Earths.[9] This is below the triple point of water, meaning that all water here sublimes straight from ice to vapour. Under certain conditions such as in brines, inside some rocks or on certain very low lying points of Mars, liquid water could be a possibility.[9] The Mars

Reconnaissance Orbiter has detected seasonal flows on mars. Although not appearing as a flowing liquid, dark patches occur seasonally in certain areas of mars and follow the pattern of gully streams.[6]

Mars also has some other major differences from the Antarctic Dry Valleys. The Atmosphere, as well as being 1/100th of the earth's pressure wise, is also made up mostly of Carbon Dioxide. The thin atmosphere in combination with the lack of a Martian Magnetic field means that high energy rays from the sun are not stopped as they are on Earth. This increased radiation poses great hazards to any life that would seek to exist here.[9]

Dust storms, sometimes spanning the entire globe can also be whipped up by strong winds. This can lower the temperature of the planet further and make this already inhospitable planet more so.[9]

So if Mars is so hostile, much more than the Dry valleys, what could possibly hope to survive there?

The answer is potentially in a microscopic photosynthetic cyanobacteria called *Chroococcidiopsis*. This microscopic organism is constantly found occurring on its own in extreme cold and dry habitats, one of which is the McMurdo Dry Valleys.[12]

In the dry valleys this organism is mainly cryptoendolithic. This means that it lives inside the rocks, protected from some of the more extreme weathering processes and temperatures of the outside. It is very slow growing, and contains the ability to shut off its metabolism in order to better cope with extremes. This is handy given that the dry valleys can see multiple freeze-thaw cycles just in one day.[10,11, 12,13]

The discovery of this hardy cyanobacteria lead some scientists to believe that it could potentially be used to begin terraforming Mars. Surviving on the red planet, slowly converting carbon dioxide to oxygen over thousands of years. This lead to attempts to discover what exactly it can stand up to.[12]

Instead of adapting to life with very little water, *Chroococcidiopsis* can undergo a process called anhydrobiosis. This literally means life without water. Shutting off all its metabolic functions it can completely dry up and await moisture in order to resume activity.[8] One particular experiment had a sample shut up in dry storage for 30 years! After the 30 years, the storage was opened, water restored, and the cyanobacteria revived and recovered rapidly.[8] In contrast, humans can go around 3 days without water before they start to be in big trouble.

In response to the radiation concerns with Mars, some subjects were submitted to huge doses of UV radiation. The results were extraordinary. It was found second only to another bacterium *Deinococcus* in its ability to resist radiation.[7] Not only this, but it was also able to repair damage to its own DNA![7] A remarkable feat given humans response to high doses of radiation tends to be cancer...

Several other tests were also performed. Its resistance to nutrient depletion, survival of chilling/thawing processes and potential space resistance to which it all performed excellently.[12]

So could this microscopic, prehistoric organism survive if left unaided on Mars?

The answer is: we still don't know. Many more tests would have to be performed before this question could be answered. Studies on how it copes with different soil compositions, water content and microgravity are some of the tests that could be done to help. More information about Mars would also be helpful. Particularly on the zones that contain the potential for liquid water.[12]

One thing we do know is that it is the most promising thing we have so far that could brave the red planet and live, especially given the possibility of genetic manipulation.[12]

Another question does arise out of this possibility though. If it can survive, and could be used to pave the way for future human colonisation, should we do it? Should we begin the colonisation of other worlds?

There are many who oppose the colonisation of space. Many reasons they have that it should not be done, that we should focus our energies elsewhere.

Expense is one. Why should governments spend money on space when they could spend it on things much closer to home? Healthcare, education, why should space be favoured over these?[4]

What about the radiation? Outside our small blue haven, the solar wind rages through the solar system. Hazardous to any living thing that might seek to venture out there.[4]

"It's too big, too hostile, there is so much that could go wrong!" the critics say.

Some also think that given our treatment and abuse of the Earth and its resources, that we do not deserve to travel to other worlds. That they should be left alone, unexploited and untainted by human influence.[4]

These are all legitimate concerns, and must be addressed before we seek to colonize other worlds.

Expense. Why should money be spent on space when it could be used here? Why should money be spent on conventional militaries when wars are now fought online, or with trade agreements in the political arena? Across the globe, money could be spent smarter, but why should it be spent on space?

From the time the human race left Africa in its travels across the globe, we have always sought new horizons. We strove always to seek what is over the horizon, to use our discoveries to improve our standards of living. Look how far we have come. From banging rocks together in caves, to curing the diseases that plagued our ancestors, and beginning to unravel the mysteries of the universe.

If we never spent any resources on that hope, that chance, that we might discover something that could improve our lives, you would not be listening to this today.

Mars is the next horizon, the next challenge. Yes it is hostile, yes space is big. Douglas Adams famously quotes in his Hitchhikers guide to the galaxy "Space… is big, really big. You would not believe how hugely mind bogglingly big it is."[14] An entertaining quote and though not scientific in nature, staggeringly accurate. The distances involved in space are so vast, they transcend human imagination and comprehension. At current levels of technology, it would take at least 6 months to even reach Mars. In contrast, that would take around 28 years if it was possible to do it on a Jet Airliner.

If we did decide to travel to Mars ourselves. That is 6 months in small, cramped confines with no external inputs. Any air, food, water or any other essential needed must be taken with us. In that time there are a lot of things that could go wrong, with zero chance of rescue or help.

So yes, it will be expensive. Yes, it will be dangerous. Why then, should we do it? Why should we go and attempt to colonise this far off planet with both ourselves, and the organisms we share our own world with? Especially after we have treated our own planet so.

Some, such as Elon Musk, the entrepreneur behind PayPal, Tesla Motors and SpaceX Rockets, see it as the next evolutionary step. Life began in the oceans, emerged to the land, flew in the skies and now has the possibility of reaching other worlds.[1]

The famous physicists Stephen Hawking and Carl Sagan see it as the only way to ensure survival of the human race and through us, all other life on the planet. Currently our small planet contains the only known life in the universe.[2]

We have never detected any alien radio signals or T.V shows. Dr Hawking explains that this tells us two things: Either we are the only civilisation for several hundred light years, or civilisations do not last very long.[3]

Any number of catastrophes could cause our extinction as a species. There is nothing to stop an asteroid or comet, such as the one that wiped out the dinosaurs, from striking us and delivering the same fate.[2]

The Earth itself, our giver of life, could take it away just as swiftly. A period of intense volcanism could darken the skies, cool the planet and cause us to freeze and starve.[14]

Having all our eggs in one basket spells almost certain doom not only for the human race, but also for all the other species we share this planet with.

Life is all we have. If we do not seek our own survival, the survival of the human race, why then, do we get up each day, work, play, hope and dream? Of course, we are not perfect. Throughout the course of human history we have made many mistakes, but if we remain trapped on this planet and perish as a result. All these mistakes would have been in vain.

So far as we know, we are Life’s only chance to endure the rigours of the universe. Improbable as it may be, our tiny planet is the only thing we know of where this amazing phenomena exists. Given that we have the capability to travel and potentially colonise other planets. Would it not be selfish to remain here, as permanent jailors awaiting the execution order to life as we know it?

As a species, we have a choice to make. Do we take the first step in the continued chance that life will carry on? Or do we isolate ourselves here, end our intrepid journey we began millennia ago, and await whatever fate the universe sends us?

All of this could be decided by one simple thing: Moving one small archaic life form from one spinning rock to another.

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